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Modelling Supergiant Pulsations

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The observational data on variable intermediate spectral type supergiants and pulsational models of supergiants are discussed.

§1. Observational data

Several groups of variable stars are found in the vicinity of the extension of Cepheid instability strip towards higher luminosities (see Fig. 1 in Becker, 1987). These fall into two categories viz. those of massive and low mass stars. These groups overlap in luminosity on the HR-diagram, what in some cases (eg. UU Her stars) leads to disputes as to which of the two categories individual groups of variable stars belong (Fernie,1983). In the case of massive stars the existing photometric and radial velocity measurements show that their variability is semi-regular and of very low amplitude $\sim 0.^{m}01$ (see eg. Rufener et al.,1977, or Fig. 1). Recently very interesting spectroscopic data have been obtained by Zeinalov and Rzaev (1990) for A-type supergiants (see their Fig. 1).

In comparison with massive stars the UU Her stars exhibit variability of higher amplitude (see Fernie, 1990 and references therein). These stars are located around the spectral type F. IRAS has detected infrared excesses in some of these stars (Parthasarathy and Pottash,1986), with the exception of UU Her itself (Tamura and Takeuti,1991)). Assuming that UU Her type stars are low mass objects (see however the discussion in Fernie and Sasselov, 1989), they are located on the HR diagram on the extension of post-AGB evolutionary tracks, at an evolutionary stage just following the cessation of strong wind during OH/IR phase. Hence, together with other types of pulsating stars they provide diagnosis of late stages of evolution and the transition to planetary nebula nuclei.

The evolution of both massive (Chiosi and Maeder,1986) and low mass stars is affected significantly by mass loss. In low mass stars its relation to pulsation is clearly established

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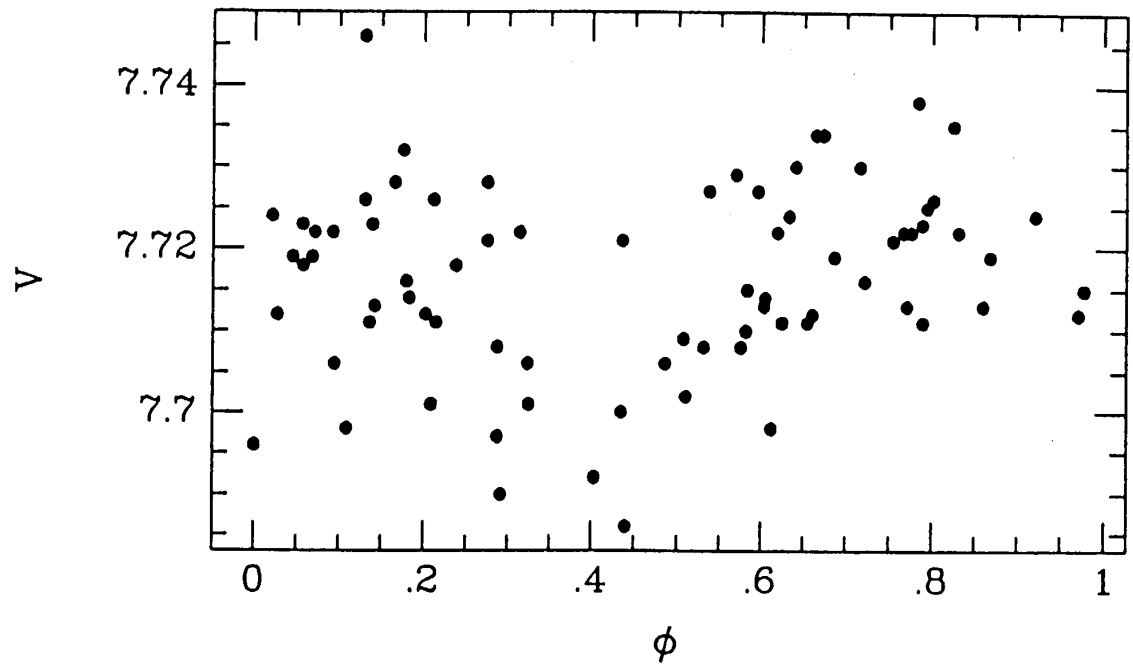

Figure 1: Photometric data for HD 17971 phased with a 'best fit' period of 27.3^d (Burki et al.,1978).

observationally (see Bedijn,1988). Maeder (1980) by examining the data on massive stars has found a correlation between observed amplitude and mass loss rate, however, due to the semiregularity of these stars no definite phase correlation has been found (Lamers,1987).

§2. Models

The observed semi-periodicities in both UU Her and massive supergiants are on the average somewhat longer than the periods expected from linear pulsation calculations. About 60% of variable massive stars have quasi-periods about 1.7 times longer than the fundamental radial mode period (Lovy et al.,1984). The periods of UU Her stars, as it is seen from Fig. 2, are also longer than those that would be expected assuming observationally derived luminosities ($L \sim 5 \cdot 10^3 L_\odot$, see van der Veen and Habing, 1990). In the case of massive stars several causes of variability have been suggested (see eg. de Jager,1987) like the radiation pressure induced instability or turbulence (Appenzeller,1986, de Jager, 1984, Maeder, 1986). Semiregular behavior has also been found in nonlinear hydrodynamical models of low mass stars (Kovács and Buchler,1988). The nonlinear models of UU Her

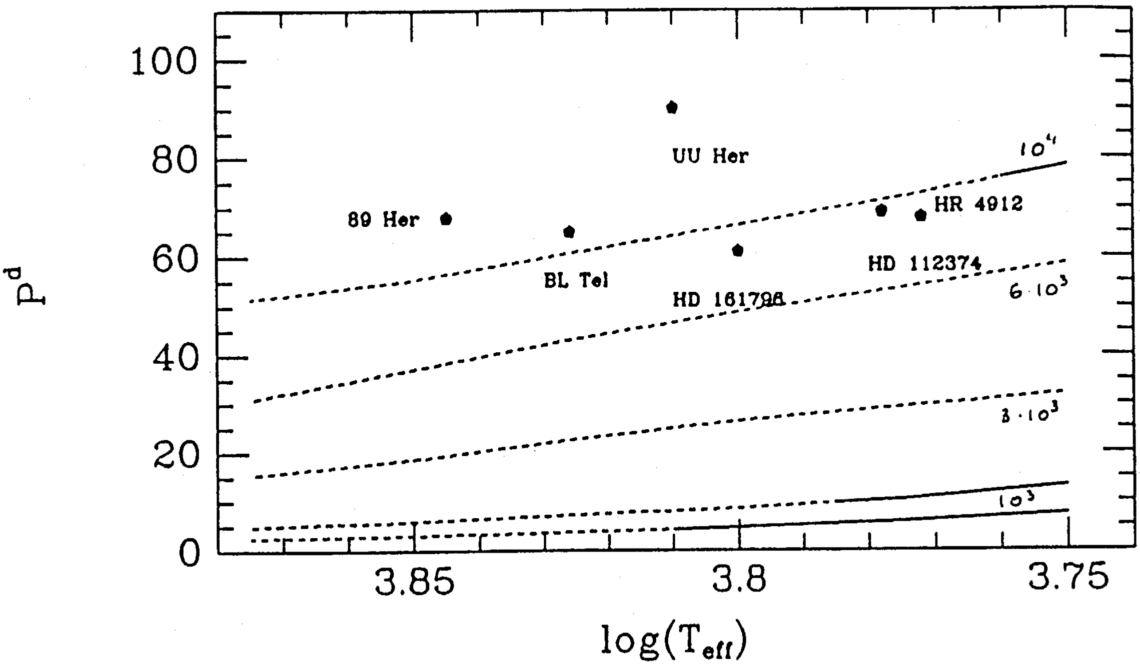

Figure 2: Comparison of observed periods of UU Her type stars (the longer periods are shown, data after Sasselov, 1983) with the linear pulsation periods for low mass stars (curves are labeled by luminosity, the corresponding mass is from Paczyński's (1970) relation).

stars obtained by Aikawa (1991) show irregular behavior with typical timescales that are longer than the period estimated from linear analysis.

Both mass loss and pulsations of high luminosity supergiants have to be studied using hydrodynamic calculations because of the strongly nonlinear nature of these processes. The application of hydrodynamic models to the Cepheid or RR Lyr variables has proved very successful, and it has also led to the discovery of new dynamical phenomena (see Buchler,1992). The development of numerical hydrodynamical models in recent years has improved the understanding of the properties of nonlinear phenomena occurring in the outer layers. At the same time the increasing number of spectroscopic observations both in the optical and infrared regions provide data that can be compared with model predictions.

The early hydrodynamical models of Cepheids (see eg. Davis (1988) and Karp (1975)) reproduced satisfactorily the observed lightcurves. Karp (1975b) has also examined the behavior of line profiles at various phases of pulsation (see his Fig. 9). The line profiles show distortions both due to differential velocity and due to shocks. When compared to observations of more luminous supergiants (see Fig. 1 in Zeinalov et al. for massive A-type supergiants, or Fig. 3 in Lèbre and Gillet,1991 for the RV Tau star R Sct) is it seen that models with significantly more extended envelopes are necessary to reproduce the observations (see eg. Mihalas et al. 1975). The available spectroscopic data on UU Her stars (see Tamura et al. 1992) indicate similar type of line profile shapes (i.e. P-Cyg, inverse P-Cyg). Recent hydrodynamical calculations including radiative transfer by Fokin (1991) essentially reproduce the line profile changes during pulsation.

While an improvement in both the theoretical understanding of the dynamics, particularly in multi mode stars, and a better description of radiative transfer, required for a comparison with lightcurve and spectroscopic observations is necessary, the accuracy of hydrodynamic models is now sufficient to allow their use as diagnostic tools. By examining *both* the pulsational properties and line forming region motions Tuchman (1991) has been able to derive new constrains on the pulsational modes of Miras . The models of Fokin (1991) allow to obtain a quantitative estimate of the velocity profile in a pulsation atmosphere and a comparison with the observed line profiles, while the models of Bowen (1990) allow to examine the dynamics of an extended pulsating atmosphere including the role of shocks and dust in promoting and sustaining mass loss.

References

Aikawa, T. 1991, *Astrophys. J.*, submitted.

Appenzeller, I. 1986, *Luminous Stars and Associations in Galaxies*, IAU Symp. 116, ed. C. de Loore and A. J. Willis.

Becker, S. A. 1987, *Stellar Pulsation*, Lecture Notes in Physics, vol. 274, p. 16, ed. A. N. Cox, W. M. Sparks and S. G. Starrfield.

Bedijn, P. J. 1988, *Astron. Astrophys.*, **205**, 105.

Bowen, G. H. 1990, *Numerical Modelling of Nonlinear Stellar Pulsation*, NATO ASI Series C, vol. 302, p. 155, ed. J. R. Buchler (Kluwer academic Publishers).

Buchler, J. R. 1992, Proc. IAU Coll. no. 134.

Burki, G., Maeder, A. and Rufener, F. 1978, *Astron. Astrophys.*, **65**,363.

Chiosi, C. and Maeder, A. 1986,*Ann. Rev. Astron. Astrophys.*, **24**,329.

Davis, C. G. 1988, Multimode Stellar Pulsations, ed. G. Kovács, L. Szabados and B. Szeidl, p 87 (Konkoly Observatory, Kultura Budapest).

Fernie, J. D. 1983, *Astrophys. J.*, **265**, 999.

Fernie, J. D. 1990, *Publ. Astr. Soc. Pacific*, **102**, 442.

Fernie, J. D. and Sasselov, D. D. 1989, *Publ. Astr. Soc. Pacific*, **101**, 513.

Fokin, A. 1991, *Monthly Notices Roy. Astron. Soc.*, **250**, 258.

de Jager, C. 1984, *Astron. Astrophys.*, **138**, 246.

de Jager, C. 1987, in *Instabilities in Luminous Early Type Stars* , ed. H.J.G.L.M. Lamers and C.W.H. de Loore, Astrophysics and Space Science Library, vol. 136, p. 191 (D. Reidel Publishing Company).

Karp, A. H. 1975, *Astrophys. J.*, **200**, 354.

Karp, A. H. 1975b, *Astrophys. J.*, **201**, 641.

Kovács, G. and Buchler, J. R. 1988, *Astrophys. J.*, **334**, 971.

Lamers, H.J.G.L.M. 1987, in *Instabilities in Luminous Early Type Stars*, ed. H.J.G.L.M. Lamers and C.W.H. de Loore, Astrophysics and Space Science Library, vol. 136, p. 99 (D. Reidel Publishing Company).

Lèbre, A. and Gillet, D. 1991, *Astron. Astrophys.*, **246**, 490.

Lovy, D., Maeder, A., Noels, A. and Gabriel, M. 1984, *Astron. Astrophys.*, **133**, 307.

Maeder, A. 1981, *Astron. Astrophys.*, **90**, 311.

Maeder, A. 1986, *Highlights of Astronomy*, p. 273.

Mihalas, D., Kunasz, P. B., Hummer, D. G. 1975, *Astrophys. J.*, **202**, 465.

Paczyński, B. 1970, *Acta Astron.*, **20**, 47.

Parthasarathy, M. and Pottash, S. R. 1986, *Astron. Astrophys.*, **154**, L16.

Rufener, F., Maeder, A. and Burki, G. 1977,*Astron. Astrophys.Suppl.*,**31**, 179.

Sasselov, D. D. 1983, *Astrophys. Space Sci.*, **102**, 161.

Tamura, S. and Takeuti, M. 1991, *Inf. Bull. Var. Stars*, 3561.

Tamura, S., Takeuti, M. and Zalewski, J. 1992, these proceedings

Tuchman, Y. 1991, *Astrophys. J.*, **383**, 779.

van der Veen, W. E. C. J. and Habing, H. J. 1990, *Astron. Astrophys.*, **231**, 404.

Zeinalov, S. K. and Rzaev, A. KH. 1990, *Astrophys. Space Sci.*, **172**, 217.